OLED

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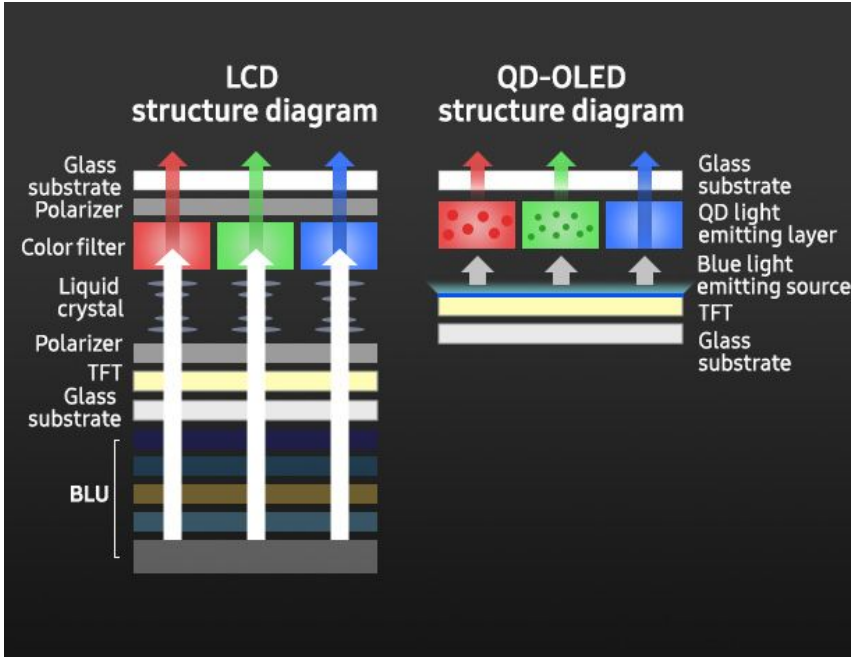
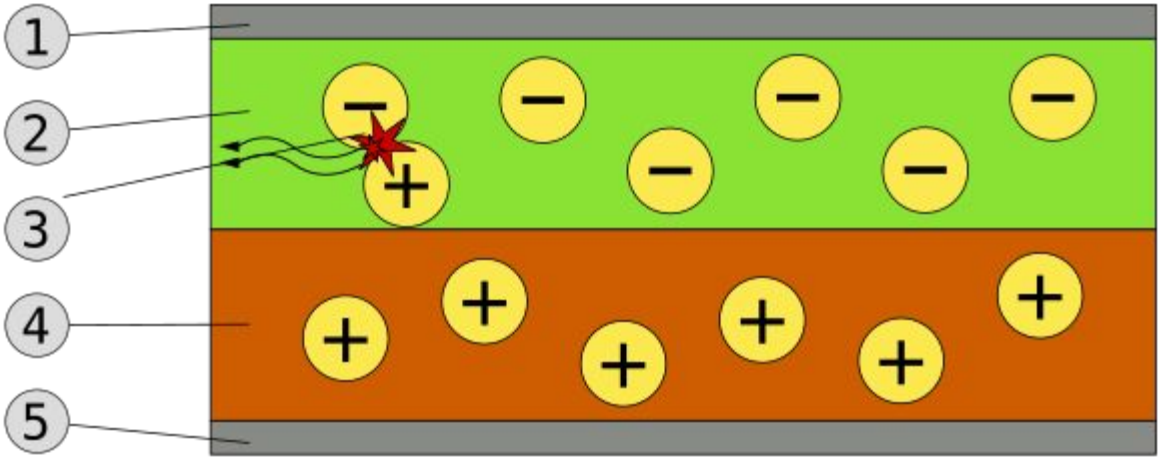
What is OLED?

OLED (Organic Light Emitting Diode) technology is **one of the greatest innovations** in the world of electronic displays. Unlike conventional LED screens, OLED panels are made of organic materials that **emit their own light when an electric current is applied.** Since its emergence in the late 20th century, OLED has been adopted in consumer devices such as smartphones, televisions, and smartwatches. Its main advantage lies in its ability to **deliver more realistic and deeper images**, thanks to its capacity to turn individual pixels on or off.



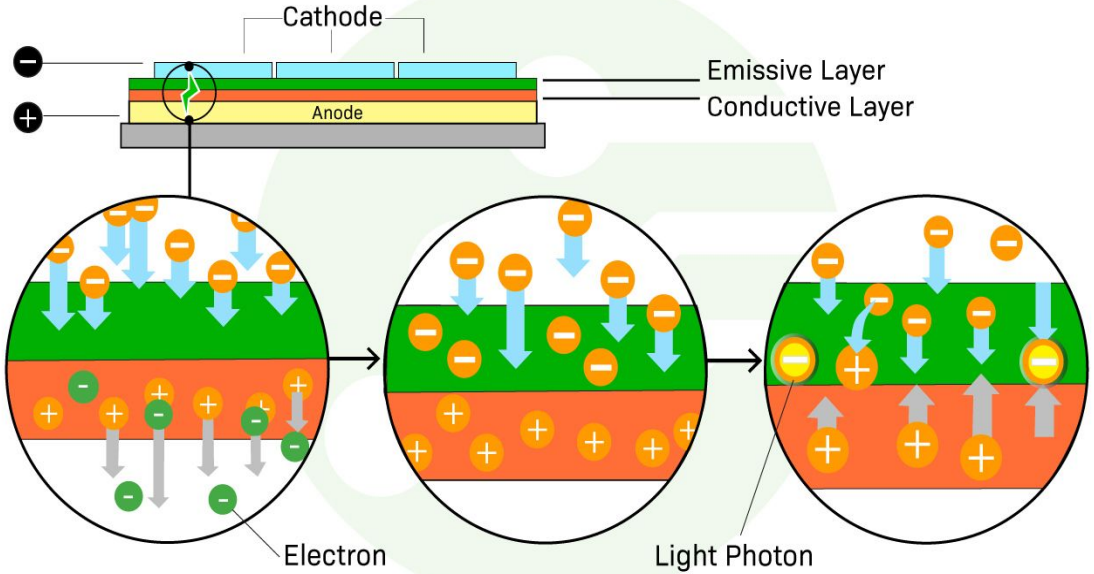
How it works?

The operation of an OLED screen is based on a **structure of thin layers composed of organic materials.** These layers are placed **between two electrodes:** a cathode and an anode. When an electric current is applied, electrons and holes combine in the emissive layer, producing light in the process. This **light can be of different colors,** depending on the compound used. Unlike LCD screens, which require a backlight source, each OLED pixel generates its own light, allowing for better brightness control and higher contrast.



- 1. Cathode (–)
- 2. Emissive Layer
- 3. Emission of radiation
- 4. Conductive layer
- 5. Anode (+)

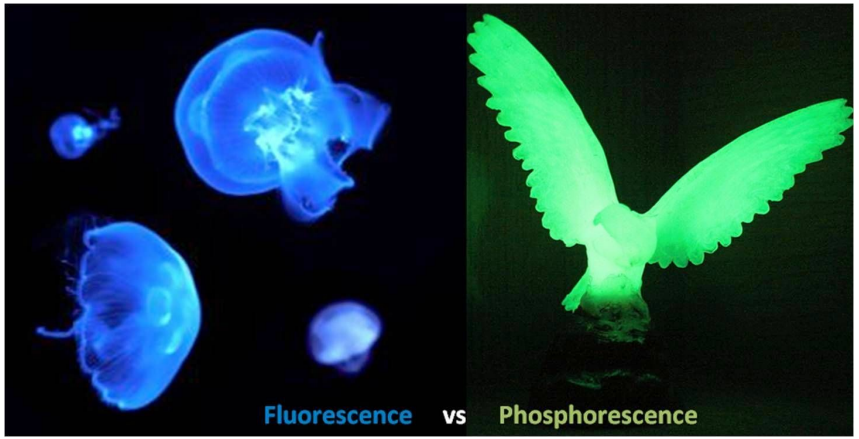
How it works?



When a voltage is applied to an OLED, **electrons enter from the cathode and "holes"** (the absence of electrons) from the anode. Both move toward the center of the device, where they meet and combine to form an exciton, which is an **excited energy state**. As this state relaxes, energy is released in the form of visible light. The color of this light depends on the energy difference between the **HOMO and LUMO** layers of the material.

How it works?

Additionally, these excitons can **have different spin configurations:** some emit light quickly **(fluorescence)** and others more slowly **(phosphorescence).** Thanks to special materials used in modern OLEDs (PHOLEDs), both types can be harnessed, thus improving the device's efficiency.



Material of an OLED screen

OLED devices use a variety of organic and inorganic materials, each with a specific function within the different layers of the device. These materials determine key properties such as emission color, efficiency, durability, and manufacturing method.

1. Conductive Materials

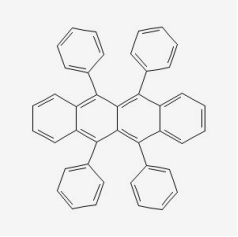
- **Indium tin oxide (ITO):**
  Used as the anode. It is a transparent and conductive material that allows light to pass through and facilitates hole injection.
- **Metals such as aluminum, calcium, or magnesium-silver (Mg:Ag):**Used as cathodes. They inject electrons from the opposite end of the device.

Material of an OLED screen

2. Emissive Materials

Small molecules (SM-OLED)

- **Advantages:** High purity, good color control, good efficiency.
- **Disadvantages:** Require vacuum deposition (costly), limited stability.

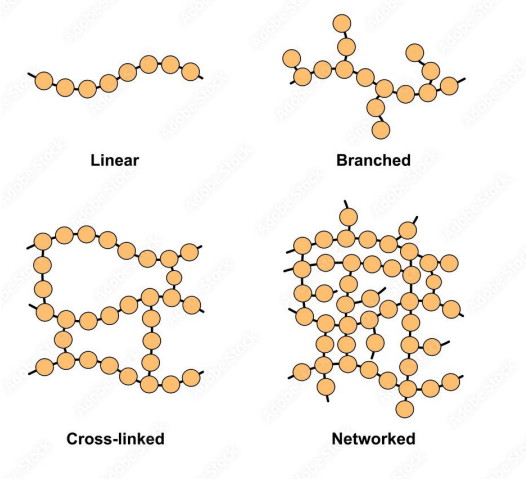


2. Emissive Materials

Polymers (PLED or P-OLED)

Examples: Polymers derived from PPV (poly(p-phenylene vinylene)) and polyfluorene.

- **Advantages:** Solution-processable (more affordable), ideal for large-area applications.
- **Disadvantages:** Less control over multilayer structures.



Material of an OLED screen

2. Emissive Materials

Phosphorescent materials (PHOLED)
Examples: Ir(mppy)$_3$ (iridium), platinum complexes.

- **Advantages:** Utilize both singlet and triplet states → internal efficiency close to 100%.
- **Disadvantages:** Higher cost, some materials still under research for certain colors (like blue).

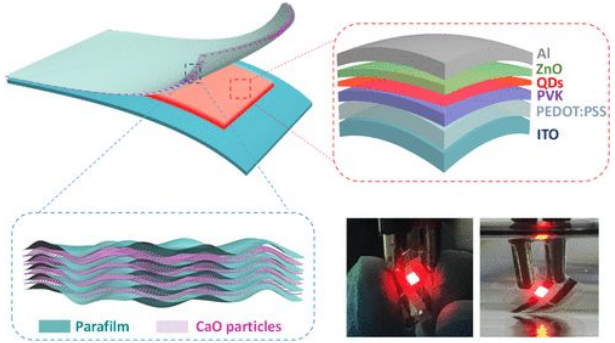
3. Transport and Injection Materials

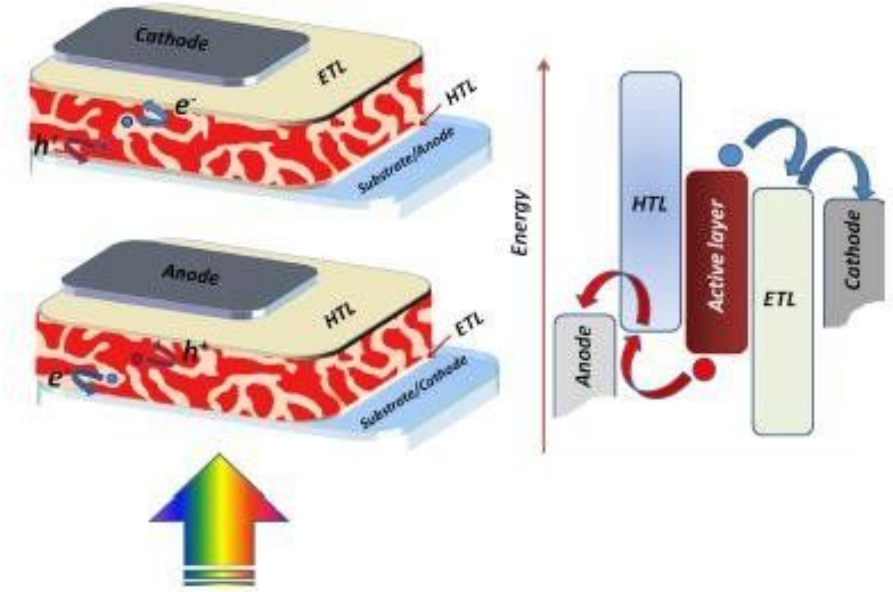
- **HTL (Hole Transport Layer)**:
  Triphenylamine and derivados, NPB.
- **ETL (Electron Transport Layer)**:
  Alq$_3$, oxadiazoles, BPhen (bathophenanthroline).

Material of an OLED screen

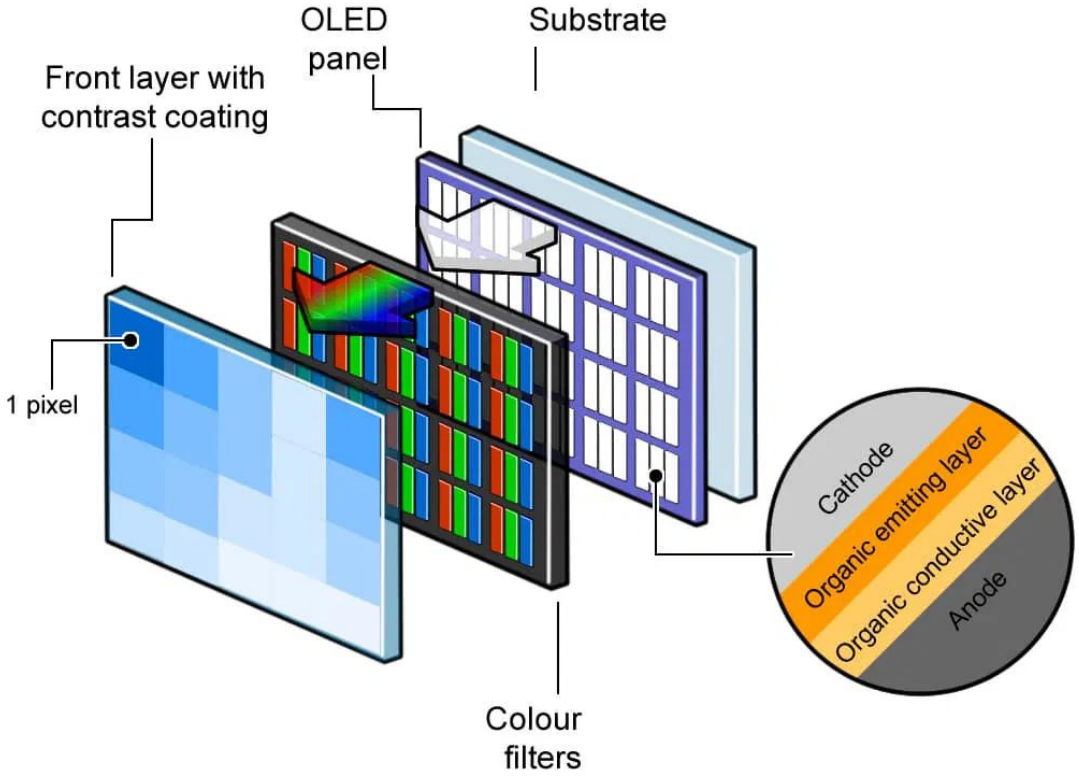
4. Encapsulation Materials

- **Glass or multilayer plastic films:** Protect the organic materials from oxygen and moisture.
- **New technologies:** Flexible encapsulation with materials such as POSS and nanoparticles.



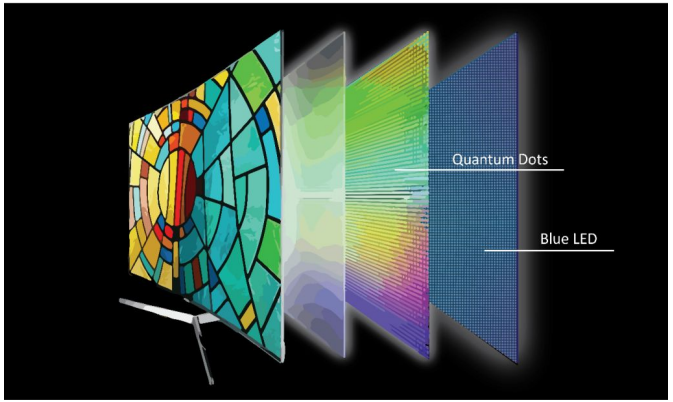


Structure of an OLED screen



Advantages of OLED

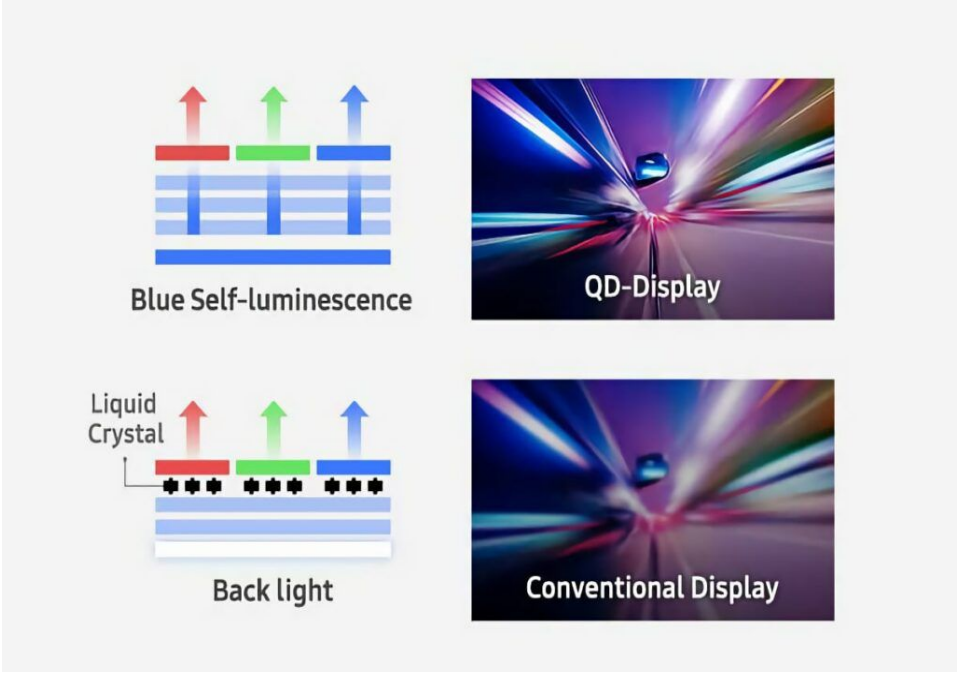
OLED screens offer several technical and aesthetic advantages. One of the most notable is their **ability to reproduce true blacks,** as the pixels can be completely turned off. This significantly enhances contrast and image depth. In addition, OLED **panels are thinner and lighter,** and can be manufactured in curved or flexible shapes, allowing for more innovative designs. They also **have a faster response time than LCD screens,** resulting in a **smoother experience—especially** in video games or fast-moving content.



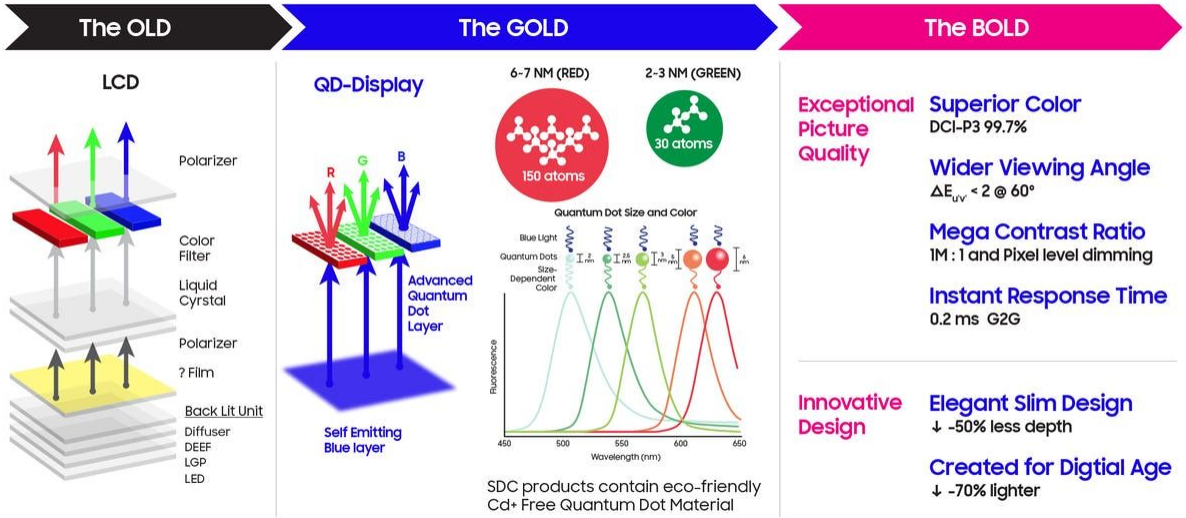
Disadvantages of OLED

Despite its advantages, **OLED technology still faces some challenges.** One of the main issues is the uneven degradation of organic materials, especially **the blue color,** which can **reduce the screen's lifespan.** Another problem is what's known as **burn-in** a permanent image retention that can occur when certain pixels display the same image for an extended period.

Additionally, the OLED **manufacturing process remains expensive,** which increases the final product cost compared to other technologies like LCD.



Future of OLED



The future of OLED is promising, with developments **focused on overcoming its current limitations and expanding its use into new sectors.** Current research aims **to improve the efficiency and durability of materials,** especially the blue component. Work is also being done on transparent and flexible OLEDs, which could be integrated into windows, smart mirrors, or clothing.

In addition, **complementary technologies like QD-OLED (Quantum Dot OLED) and alternatives such as MicroLED** offer new possibilities, although OLED remains a leader in image quality and adaptability.